Environmental Impact of Neonicotinoid Treated Seeds Literature Review for the AIB

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Presented by:

Jill M.G. Chapleau Goss, Feed, Seed & Fertilizer Specialist

Morgan Griffith, Agrichemical Program Manager

Vermont Agency of Agriculture, Food & Markets

Notes on paper selections

Selected papers published from 2018 and 2023

Selected papers dealing with neonicotinoids applied specifically as seed treatments

Excluded papers on human heath as these will be reviewed by Sarah Owens from Vermont Department of Health

Selected papers dealing with off target impacts of neonicotinoid seed treatments

Reviewed AIB member suggestions that fit above criteria

Utilized Google Scholar to search for the following terms:

- neonicotinoid seed treatments, with a custom range 2018-2023
- off target neonicotinoid seed treatment, with a custom range 2018-2023

Sowing Uncertainty: What We Do and Don't Know about the Planting of Pesticide-Treated Seed

- Treated seed sales increased from $200 million in 1990 to over $1 billion in 2008
- Broadened use of seed treatments as companies often bundling of treatments and desirable GE traits with no untreated version available.
- Treated seeds sales increased yet farmer’s knowledge decreased on the specific treatments applied to their seed:

e.g., Fungicide seed treatments on corn seed nearly universal

in 2016 survey of corn fields only 28% of farmers indicate they utilized a fungicide seed treatment

Sowing Uncertainty: What We Do and Don't Know about the Planting of Pesticide-Treated Seed

Inconsistent/limited data pose an impediment to the deliberations by policy makers on pesticide policy and mitigation efforts.

Evidence for current overuse of pesticide can be presumed in not only the lack of availability of untreated seed but also in the farmers' inability to accurately report the pesticides applied to their seeds

Environmental Risks and Challenges Associated with Neonicotinoid Insecticides

- "…seed coatings can lessen the amount of overspray and drift, the near universal and prophylactic use on major agricultural crops has led to widespread detections in the environment (pollen, soil, water, honey)."
- "Pollinators and aquatic insects appear to be especially susceptible to the effects of neonicotinoids with current research showing that chronic sublethal effects are more prevalent than acute toxicity."
- "Meanwhile evidence of clear and consistent yield benefits from the use of neonicotinoids remains elusive for most crops."

Environmental Risks and Challenges Associated with Neonicotinoid Insecticides

- Neonicotinoids are highly water soluble, persistent in soils and waters and easily shifted from their intentional locations to non-targeted locations.
- ~5% of the neonicotinoid treatments applied get absorbed by the crop while the remaining ~95% either remain in soil or soil water with less than ~2% lost as dust off during the planting process.

[Environmental Risks and Challenges Associated with Neonicotinoid Insecticides]

- In soils of fields where treated seeds are planted, neonicotinoids increase during each subsequent planting year appearing to plateau off after approximately 5 years of use but persist several years after their use is discontinued.
- Water sampling study for multiple neonicotinoids at least one neonicotinoid detected in 76% of sampling in highly cultivated and in 53% of sampling in mixed land use areas in a study of USA Midwest.
- Detections likely coming from multiple sources such as overspray, particulates, seed treatments, soil applications, etc.

[Environmental Risks and Challenges Associated with Neonicotinoid Insecticides]

- 75% of honey sampled around the world contained least one neonicotinoid, 45% of these contained multiple neonicotinoids
- Swedish full field study"…bumblebee colonies placed next to oilseed rape fields treated with clothianidin performed markedly more poorly than controls."
  - Adjacent to the treated fields, Osmia bicornis, mason bees "failed to breed entirely" while "honeybee hives showed no measurable effects."
  - Full field studies in Germany, Hungary and the United Kingdom presented similar results:"…clear adverse effects on bumblebees and mason bees (*Osmia*) and variable effects on honeybees….Some field trials have found no negative impacts" on honeybees.
- UK study demonstrated predictions could be made on declines in wild bee populations utilizing "regional patterns of neonicotinoid use." Further studies in CA and U.K. mirrored results.

Environmental Risks and Challenges Associated with Neonicotinoid Insecticides

- Neonicotinoids particularly toxic to aquatic insect species that “support aquatic and terrestrial food webs.”
- Direct consumption of treated seed by granivorous birds can induce lethal or sublethal effects such as: impacts on reproductive ability, impaired orientation in flight or loss of body mass.
- Indirect effects possibly a depletion food sources for insectivorous birds.

Environmental Risks and Challenges Associated with Neonicotinoid Insecticides

- Multiple neonicotinoids + metabolites + environmental degradates=concern for toxicity potential.
- “degradation may not infer reduced toxicity”
- Historically approximately 35% of maize acres in the USA were treated with an insecticide, now treated seed has increase use with ~100% of maize crops planted in the USA and canola crops planted in Canada coated with a neonicotinoid seed treatment. Canada conservative estimate say neonicotinoid treated acres increased 30% neonicotinoid treated acres from 2009-2012 alone.
- Yield benefits varied depending upon crop type.
- Timing of seed treatments may not coincide with the point of highest pest pressures.
- “…As currently used (seed treatments) are violating key principals in integrated pest management because prophylactic neonicotinoid treatments are targeting ‘occasional pests’ and there is evidence that pest resistance is increasing with increasing neonicotinoid use.”

Year-round presence of neonicotinoid insecticides in tributaries to the Great Lakes, USA

- Study of 10 major tributaries to the Great Lakes
- Monthly samples collected October 2015 through September 2016
- 74% of all samples contained at least one neonicotinoid with up to three neonicotinoids detected in up to 10% of samples
- In areas cultivated crops were present concentration of clothianidin and thiacloprid increased significantly while in urbanized areas detections of imidacloprid were increased.
- Highest levels of neonicotinoids detected in summer months yet were present throughout the year.

Year-round presence of neonicotinoid insecticides in tributaries to the Great Lakes, USA

- **Maximum individual neonicotinoid level detected in a sample: 330 ng L^{-1}**
- **Maximum total neonicotinoid levels detected in a sample: 670 ng L^{-1}**
- **Median detected neonicotinoid level detected: 7.0-39 ng L^{-1}**

[Year-round presence of neonicotinoid insecticides in tributaries to the Great Lakes, USA]
Table source: Hladik, M. L. (2018). Year-round presence of neonicotinoid insecticides in tributaries to the Great Lakes, USA. Environmental Pollution, page 17.

Toxicity value comparsion for three neonicotinoids. CLO = clothianidin; IMD = imidacloprid; THX = thiamethoxam; NA = not available.

Source		Value (ng L^{-1})			# of Exceedances		
		CLO	IMD	THX	CLO	IMD	THX
USEPA Aquatic Life Benchmark –	acute	11,000	385	17,500	0	0	0
Invertebrates (USEPA, 2017a)	chronic	1,100	10	NA	0	33	NA
Morrissey et al. (2015)	acute	200	200	200	3	1	0
	chronic	35	35	35	12	8	6

Year-round presence of neonicotinoid insecticides in tributaries to the Great Lakes, USA

- "…evidence of potential for chronic toxicity impacts through the near constant neonicotinoid exposure to individual taxa as well as on ecosystem functions….More research is needed on the potential effects of year-round neonicotinoid exposures."

Grout, T. A., Koenig, P. A., Kapuvari, J. K., McArt, S. H. (2020). Neonicotinoid Insecticides in New York State: Economic benefits and risk to pollinators. Section 6.3 Environmental fate of neonicotinoid insecticides *Cornell University Extension,* 195-198.

Neonicotinoid Insecticides in New York State: Economic benefits and risk to pollinators

Section 6.3 Environmental Fate of Neonicotinoid Insecticides

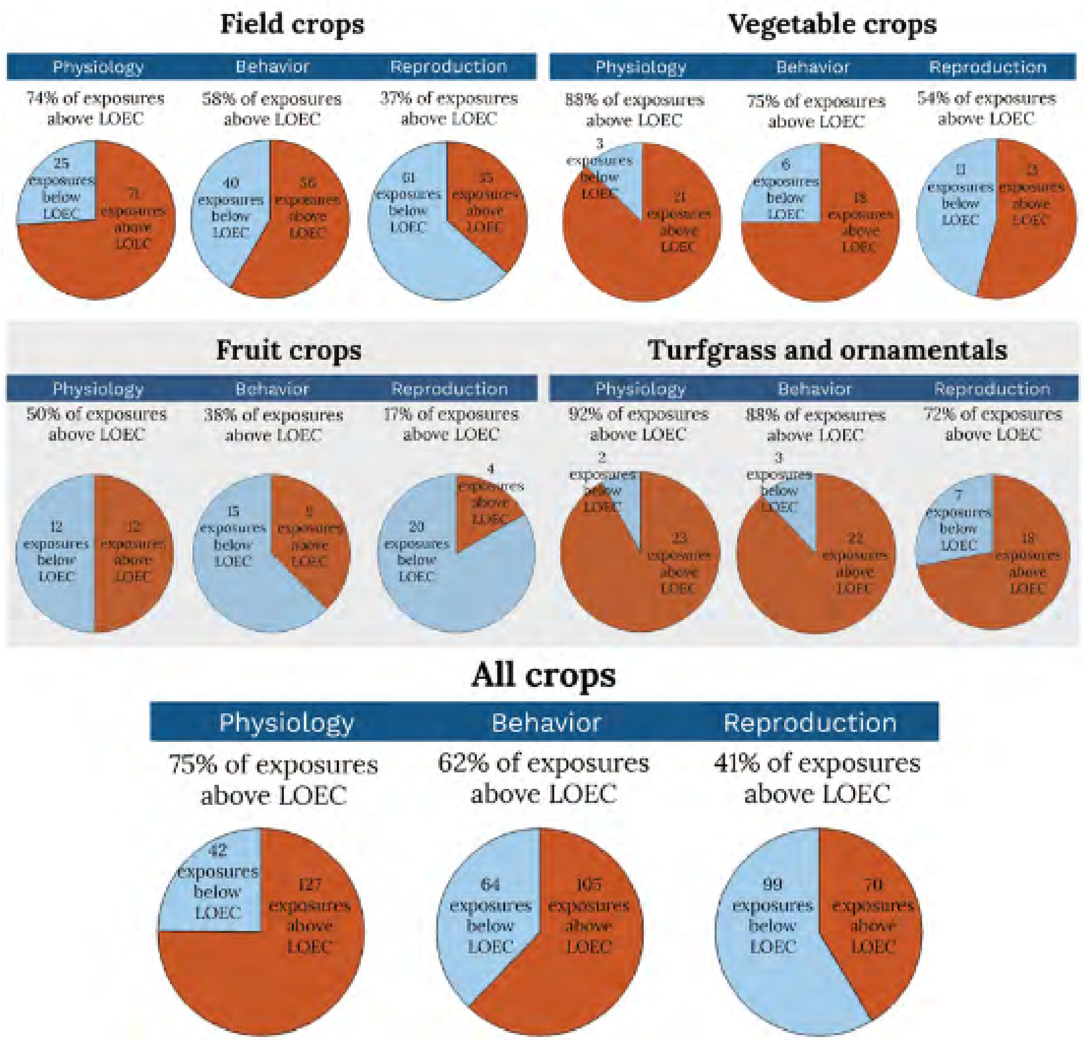
- Pollinator exposures from treated seeds via dust drift or persistence and transport within environment
- Dust drift can be mitigated by using appropriate seed coating formulations and lubricants, redirecting or filtering exhaust of planters and avoiding planting during dry and windy conditions
    - Advanced seed lubricants (compared to talc or graphite) significantly reduce dust from abrasion
    - Mechanical-type planters produce less dust than vacuum-type
- Plant absorbs 1.6-20% of active ingredient on treated seeds depending on crop and environmental conditions
- Persistence of neonicotinoids in soil depends on pH, temperature, moisture content, organic matter, root systems, and soil structure and texture.
    - Half-lives of neonicotinoids in soil ranged from fewer than 90 days (dinotefuran) to several years (over 8 years for imidacloprid and 19 years for clothianidin).
- Persistence of neonicotinoids in water depends on pH and UV radiation.
    - When in surface water and exposed to sunlight the half-lives of imidacloprid, clothianidin and thiamethoxam are short (<3.5 days) and half-lives of thiacloprid and acetamiprid are slightly longer (8-68 days).
- Breakdown of neonicotinoids in soil and water does not make them harmless because some breakdown products are more toxic or similarly toxic to bees

Grout, T. A., Koenig, P. A., Kapuvari, J. K., McArt, S. H. (2020). Neonicotinoid Insecticides in New York State: Economic benefits and risk to pollinators. Section 6.3 Environmental fate of neonicotinoid insecticides *Cornell University Extension,* 195-198.

Neonicotinoid Insecticides in New York State: Economic benefits and risk to pollinators

Section 6.3 Environmental Fate of Neonicotinoid Insecticides

Figure 6.6: Observed neonicotinoid exposures to bees in field crops, vegetable crops, fruit crops, and turfgrass & ornamentals settings compared to the lowest observed effects concentrations (LOECs) for honey bee physiology, behavior, and reproduction.



Notes: Risk using the LOEC-based approach uses mean exposure levels in a particular study and setting (e.g., mean clothianidin levels in pollen collected from a particular study in corn fields) and compares each value quantitatively to the LOEC for each effects category (physiology, behavior, reproduction). Here we include all exposure data (i.e., data where no neonicotinoids were detected and data where neonicotinoids were detected) in analyses, thus providing the most realistic picture of risk from neonicotinoids in each setting.

McArt, S., & Grout, T. (2020). Notes from the Lab – September 2020 Neonicotinoid insecticides: When there's risk to bees, when there are economic benefits to users, and when there are viable replacements. *American Bee Journal, 160*(9), 1019-1022.

Notes from the Lab – September 2020 Neonicotinoid insecticides: When there's risk to bees, when there are economic benefits to users, and when there are viable replacements

- Risk from neonics is often high in field crops settings. There is less data available to review to assess for risk in other settings
  - In and near corn and soybean fields that are planted with NTS, 74% of exposures are likely to impact honey bee physiology, 58% of exposures are likely to impact honey bee behavior, and 37% of exposures are likely to impact honey bee reproduction.
- There are hundreds of studies that assessed hazard from neonics (i.e. how doses of neonics impact bee mortality, reproduction, behavior and physiology), but few studies assess exposure to bees in the settings where neonics are used (in the field).

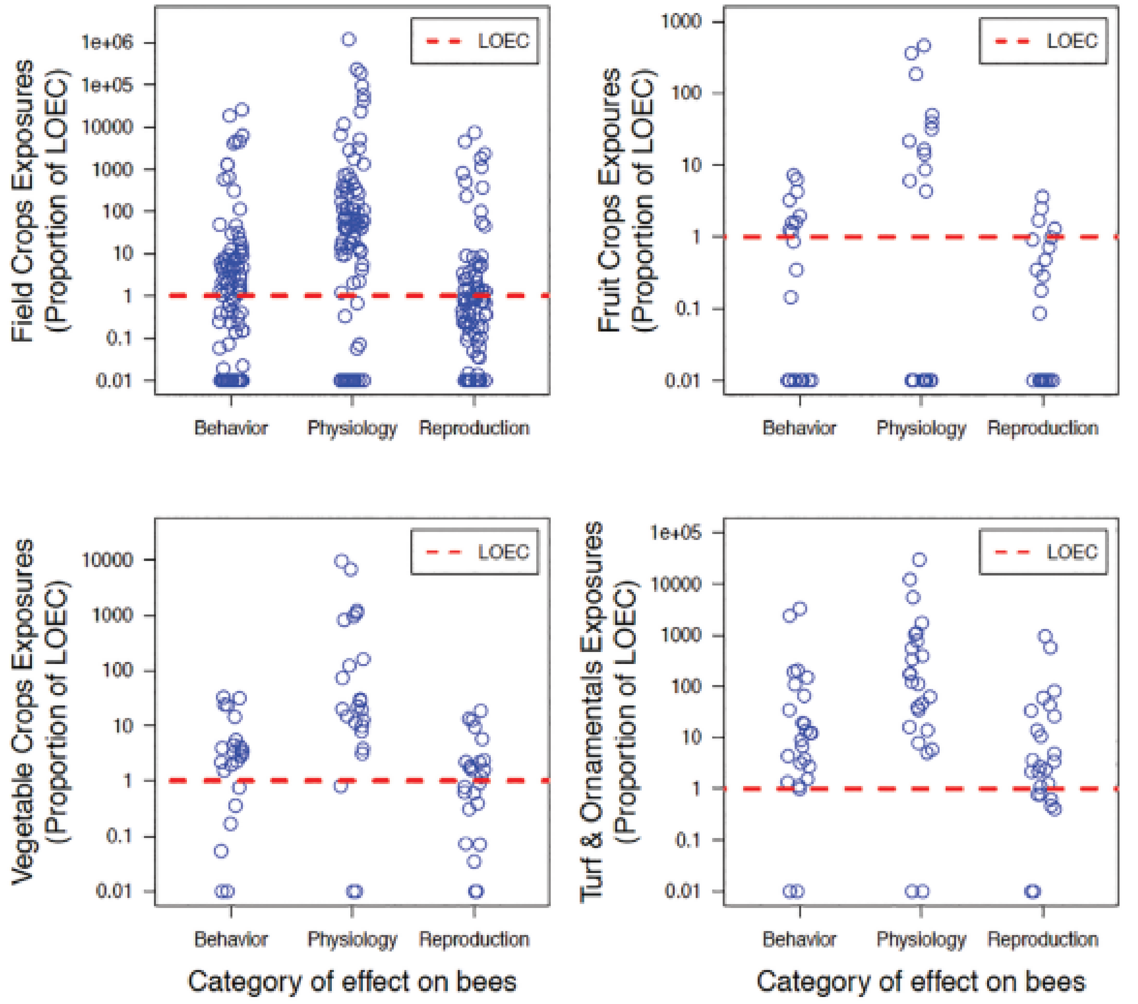


Fig. 1 *Quantitative neonicotinoid exposures to bees in field crops, fruit crops, vegetable crops, and turf & ornamentals settings expressed as a proportion of the lowest observed effect concentrations (LOECs) for adverse impacts on honey bee behavior, physiology, and reproduction. Dashed line (at y = 1) indicates the LOEC for each response. Thus, all data points above the dashed line are above the LOEC and indicate risk, while all data below the dashed line are below the LOEC and indicate no risk. Mean values for each individual study and setting are represented by open blue circles; each mean value includes all neonicotinoid exposure data (including zero values) from each study. Note that because the log of zero is undefined, all zero values (i.e., when no neonicotinoids were found) were set to 0.1 in this figure. Data points are jittered in each effects category to improve visualization.*

Alford, A. M., & Krupke, C. H. (2019). Movement of the neonicotinoid seed treatment clothianidin into groundwater, aquatic plants, and insect herbivores. *Environmental Science Technology, 53*(24), 14368-14376.

Movement of the neonicotinoid seed treatment clothianidin into groundwater, aquatic plants, and insect herbivores

- Study Objectives
  - Quantify the leaching potential of neonicotinoid treated seeds (NTS) through the growing season in Indiana corn
  - Use neonic concentrations found in lab experiments with duckweed and water lily aphids to see potential impacts to higher trophic levels
- Water samples from tiles drains in 3 crop groups were analyzed:
  - corn plots (1.25mg/kernel clothianidin)
  - NTS-free soybean plots
  - NTS-free control plots (NTS-free variable annual crops)
- Clothianidin never > 0.1ppb in control plots
- Maximum 3.37ppm collected after rainfall event 4 weeks post-plant in corn plots
  - Max concentration is 10x higher than previous research of levels in surface water because no dilution or photodegradation
- Duckweed grown in clothianidin-contaminated water showed rapid uptake of clothianidin, but aphids were unlikely to suffer acute mortality when fed on duckweed for 48 hours

Hall, M. J., Zhang, G., O'Neal, M. E., Bradbury, S. P., & Coats, J. R. (2022). Quantifying neonicotinoid insecticide residues in milkweed and other forbs sampled from prairie strips established in maize and soybean fields. *Agriculture, Ecosystems & Environment, 325*, 107723.

Quantifying neonicotinoid insecticide residues in milkweed and other forbs sampled from prairie strips established in maize and soybean fields

- Objective: understand pesticide exposures to pollinator habitat near crop fields
- Quantified concentrations of clothianidin, thiamethoxam, and imidacloprid in soil and leaf tissue in reconstructed prairies near corn or soybean fields in Iowa
- 100% of soil, 80% of vegetation from blooming forbs, and 80% of milkweed leaf tissue had at least one neonicotinoid present above the detection limit (0.07-0.9 ppb)
- Maximum concentrations detected in milkweed leaf tissue are 10-130x lower than the chronic dietary LC_{10} values for monarch butterfly larvae
  - Exposure to monarch larvae is below threshold of concern
  - Route of exposure unlikely to cause adverse effects
- Most likely exposure route to non-target plants is surface/subsurface runoff because did not see spike in concentration in foliar samples after planting (as would result from dust drift).

Main, A. R., Webb, E. B., Goyne, K. W., Abney, R., & Mengel, D. (2021). Impacts of neonicotinoid seed treatments on the wild bee community in agricultural field margins. *Science of The Total Environment, 786*, 147299

Impacts on neonicotinoid seed treatments on the wild bee community in agricultural field margins

- 2 year field study (2017-2018, Missouri) to quantify neonic concentrations in soils and flowers of ag fields and their margins and assess potential influence on bee nest and diet guild abundance.
  - 23 soybean fields with 3 treatments
    - Untreated (no prior neonic use)
    - Treated (continuously cropped with NTS for >5yrs)
    - Previously Treated (untreated, but NTS used prior to 2017)
- Neonicotinoids were detected infrequently in both years within margin flowers (0%), soybean flowers (<1%), margin soils (<8%), and field soils (39%)
- Presence of neonicotinoids in field soils reduced richness of wild bee nest and diet guilds living in or near agricultural fields over the two seasons, but annual treatment did not show a significant difference

Table 2

Frequency of detection (%) and median concentration (μg/kg) of clothianidin and imidacloprid in soils collected from study fields during May to September of 2017 and 2018. "–" indicates no median value due to neonicotinoids not being detected during that sampling period (month).

	Soil conc. (μg/kg)	Untreated ($n = 7$)		Prev. Treated ($n = 8$)		Treated ($n = 8$)	
2017	Clothianidin	% detects	Median	% detects	Median	% detects	Median
	May	0	–	13	6	0	–
	June	0	–	13	7	13	15
	July	0	–	13	10	13	12
	August	0	–	13	10	13	11
	September	0	–	13	27	13	8
	Imidacloprid	% detects	Median	% detects	Median	% detects	Median
	May	0	–	25	3	0	–
	June	0	–	13	4	50	8
	July	0	–	13	3	38	5
	August	0	–	50	3	75	3
	September	0	–	25	3	63	11
2018	Clothianidin	% detects	Median	% detects	Median	% detects	Median
	May	0	–	38	16	13	19
	June	0	–	0	–	0	–
	July	0	–	38	19	50	18
	August	0	–	38	20	50	27.5
	September	0	–	50	11	50	22.5
	Imidacloprid	% detects	Median	% detects	Median	% detects	Median
	May	0	–	13	8	25	6.5
	June	0	–	13	6	75	15
	July	0	–	0	–	100	10
	August	0	–	0	–	75	16
	September	0	–	38	4	100	12

MacDonald, A. M., Jardine, C. M., Thomas, P. J., & Nemeth, N. M. (2018). Neonicotinoid detection in wild turkeys (Meleagris gallopavo silvestris) in Ontario, Canada. *Environmental Science and Pollution Research, 25*, 16254-16260

Neonicotinoid detection in wild turkeys (Meleagris gallopavo silvestris) in Ontario, Canada

- Study Objective
  - Test for presence of neonics in terrestrial vertebrates that consume NTS, such as wild turkeys in Ontario
  - Analyzed livers of 40 wild turkeys taken during hunting season
- Maximum concentrations detected were below acute toxicity LD_{50} values that exist for select birds: 14 ppm for gray partridge, 31 ppm for Japanese quail, and 152 ppm for northern bobwhite quail
- Additional research is required to determine chronic health and reproductive effects on wild turkeys and other wildlife that may occur with repeated exposure and ingestion of NTS

Table 1 Summary of detectible levels of pesticide residues in livers of hunter-harvested wild turkeys ($n = 40$) in April–May 2015, from Ontario, Canada

Pesticide	Main use	No. of turkeys (%)	MDL (ppm)	Range (ppm)
Clothianidin	Insecticide	8 (20.0)	0.001	0.0086–0.1200
Thiamethoxam	Insecticide	3 (7.5)	0.001	0.0110–0.1600
Fuberidazol	Fungicide	2 (5.0)	0.0005	0.0077–0.0094

MDL minimum detection limit